

Campanian-Maastrichtian planktonic foraminifera at Tercis les Bains (Landes, France); synthetic view and potential for global correlation

G. S. Odin, J. A. Arz, M. Caron, J. Ion & E. Molina

Sommaire

Ce chapitre présente la synthèse des résultats acquis au cours des recherches développées par le Groupe de Travail Maastrichtien sur les foraminifères planctoniques de Tercis. Comme pour tous les groupes fossiles d'intérêt stratigraphique, les recherches ont été effectuées indépendamment par plusieurs experts ou groupes d'experts. Ceci a permis de découvrir dans la succession une variété de taxons dont la présence n'était pas évidente au vu des études préliminaires dont certaines avaient laissé supposer que ce groupe fossile ne pouvait pas être utilisé avec profit dans cette série. Les deux techniques par lavage et par lames minces ont été mises en oeuvre pour tenter de caractériser près de 200 niveaux essentiellement concentrés de part et d'autre de la limite d'Étages.

Bien que la collecte de formes en bon état se soit révélée délicate, environ 125 formes dont un genre et deux espèces nouvellement établies dans ce volume par J. Ion ont été identifiées; une grande partie est illustrée ou réillustrée dans ce volume. Certaines formes ont une utilité biostratigraphique de premier ordre telles que *Heterohelix glabrans*, *Radotruncana calcarata*, *Rugoglobigerina hexacamerata*, *Rg. rotundata*, *Contusotruncana contusa*, *Rugoglobigerina scotti*. D'autres apportent des informations complémentaires utiles telles que *Globotruncanella havanensis*, *Globotruncanina stuarti*, plusieurs espèces de *Marginotruncana*. Le reste de la faune est constitué de taxons dont la

durée de vie est trop longue pour permettre des subdivisions et corrélations dans l'intervalle concerné; d'espèces dont la distribution stratigraphique semble dépendre de l'environnement local plus que de facteurs évolutifs comme c'est le cas pour *Gansserina gansseri*; de taxons dont la définition est interprétée différemment par les divers auteurs, comme pour *Globotruncanina elevata* qui, sans cela, pourrait se révéler un marqueur utile ou *Globotruncana aegyptiaca* ou *Contusotruncana walfischensis*; enfin, de formes dont la répartition stratigraphique est encore mal connue.

La découverte la plus significative est sans conteste celle de *Rd. calcarata*. L'absence de ce taxon était suggérée dans plusieurs études précédentes, ce qui était considéré comme une déficience de la succession de Tercis très regrettable pour son rôle de succession de référence globale. Désormais, la présence établie de cet important marqueur, illustrée encore dans le présent chapitre, constitue un point fort de l'affleurement dans son rôle de section de référence.

La succession des apparitions et disparitions tout le long de la succession sédimentaire considérée ici et qui a enregistré environ 6 Ma de dépôts successifs, semble se faire sans à-coups. Ceci est interprété comme la marque d'une absence probable de lacune de dépôt suffisamment importante pour se refléter dans cette distribution. Une subdivision en quatre biozones est proposée pour la série avec une biozone à *G. ventricosa*/*G. rugosa*, une biozone à *Rd. calcarata* qui est la zone classique

d'existence limitée par l'apparition et la disparition de ce marqueur, une biozone à *Gl. havanensis*-*Rg. rotundata* qui renferme les marqueurs - le premier apparaissant près de sa base, le second un peu plus haut - mais est d'abord l'intervalle entre les biozones précédente et suivante, une biozone à *Rg. scotti*/*Ct. contusa* dont la base est définie par l'apparition sub-contemporaine de ces deux biomarqueurs. Les limites ont été localisées à 50 cm près au niveau des cotes 40,8–62,5 et 116,2 telles qu'elles sont notées dans l'affleurement principal du site (fronts de carrière).

Un autre intérêt du site de Tercis est qu'il permet de confronter les résultats d'études d'une variété de groupes fossiles, en particulier les foraminifères impliqués ici et les ammonites. Pour la première fois, il est possible de mettre en corrélation directement la biozone constituée par l'intervalle d'existence de *Bostrychoceras polyplacum* avec la biozone à *Rd. calcarata*. Cette dernière est, pour l'essentiel, postérieure à la précédente, avec un recouvrement de l'ordre de 4 m qui représentent environ 0,15 Ma de dépôt. L'intervalle d'existence de *Nostoceras hyatti* à Tercis correspond pratiquement à l'essentiel de notre biozone à *havanensis*. L'apparition sub-contemporaine de *Rg. scotti* et de *Ct. contusa* est très proche de celles de *Pachydiscus neubergicus* et de quelques autres ammonites connues pour caractériser ailleurs des couches d'âge maastrichtien.

La limite Campanien-Maastrichtien telle qu'elle est définie dans ce volume est approchée de très près par la limite entre nos biozones à *havanensis* et à *scotti/contusa*.

Si nos études à Tercis se sont essentiellement restreintes au voisinage de la limite entre les Étages, quelques observations sur la suite du Maastrichtien ont montré que le site pourrait aussi livrer une information utile pour l'ensemble de cet Étage.

1. Introduction

The planktonic foraminifera of the sediments deposited at Tercis do not easily deliver information. Caron & Odin (this volume, chap. C5a) report that a quick study gives a pessimistic view on the usefulness of this fossil group for the character-

isation of our deposits. Two micropalaeontological studies were published during the research developed by the Maastrichtian Working Group. They were undertaken on two independent sample collections gathered long before the first precise description of the succession was prepared for the working group (Odin & Odin, 1994). For this reason and, at that time, the lack of understanding of the few but real tectonical problems in some portions of the quarry (Rocher, this volume, chap. A6), it is not possible to locate the levels (or beds, or members) quoted by the previous authors precisely with regard to our description (this volume, chap. B1a). Therefore, these recently published results cannot be used for the definition of the stage boundary. However, the two studies are of interest since they give an idea of the microfossil content of the series.

As soon as 1991, Ward & Orr (1991, and personal communication to G.S.O.) prepared a preliminary manuscript where they quoted the presence of planktonic foraminifera apparently identified from washed residues. They suggested the presence of five biozones later reduced to four, due to the reinterpretation of "the presence of distinctive spines in the residues" previously believed to pertain to *Radotruncana calcarata* (Ward & Orr, 1997). The four planktonic foraminiferal biozones of 1997 were based on "globotruncanids which were found to be biostratigraphically useful throughout the entire section". The *Globotruncana ventricosa*, *Globotruncana falsostuarti* (FO at level 90), *Gansserina gansseri* (FO at level 155) and *Abathomphalus mayaroensis* (FO not shown) zones were said to be documented by the presence of the index taxa and other contemporaneous forms which were not illustrated. Ward & Orr (1997) wrote that they identified about 60 taxa (possibly including some benthic forms such as several *Bolivinoidea* - the full list is not given). They gave the approximate range of 15 planktonic forms considered significant but did not show from where they were actually observed. Finally, they noted that "most species are represented by only a few specimens in two or three separate samples" among a number of samples - which is not specified - and collected from between the base of our d'Avezac Unit and the top of our

Bédât Unit. The results published by Ward & Orr do not allow to document the succession at Tercis precisely with planktonic foraminifera but the authors clearly state that the fossil group is represented in the succession, that the dominant globotruncanid specimens have a "clear Tethyan (tropical) complexion", and that several key forms are present (although not *Rd. calcarata*).

The contemporaneously published paper by Simmons et al. (1996) is considered to be the first published attempt at establishing a distribution. It is interestingly based on the study of thin sections for the majority of samples. In that study, the microfauna which comprises about 15 determined species (the key ones are illustrated), is said to be "of limited abundance and diversity . . . whilst being of Tethyan aspect . . . many key taxa are absent, rare or unusually small". The authors note that *Rd. calcarata* "is apparently absent at Tercis (although they) have made a particularly careful search for it" but also that this "warm water, Tethyan species was able to penetrate the Bay of Biscay" in agreement to its observed presence in Hole 401 of DSDP Leg 48. The distribution is poorly documented but the authors have undertaken a comparison between the stratigraphical location of some identified forms and that of the macrofauna previously studied from the same succession. They note the presence of particular forms of *Globotruncana ventricosa* (often referred to as *G. tricarinata*) which, elsewhere, "commonly occur in the lowermost Maastrichtian" and, at Tercis, would be present in their bed N2, from where the ammonite *Pachydiscus neubergicus* was collected. The distribution of *G. tricarinata* is not shown in their table however.

Another criterion considered significant is the presence of *Globotruncanita elevata* (*sensu stricto*) which is said to become extinct in their bed N1. This extinction is suggested as a possible marker for the proximity of the Campanian-Maastrichtian boundary. According to Simmons et al. (1996), *G. elevata* is a "markedly asymmetrical, single keeled globotruncanid, with a pronounced central cone on the spiral side and a highly developed last chamber where the keel can be higher than the surface of the spiral side". The definition is important because on the one hand the form was not quoted in the

selected list of Ward & Orr (1997) and, on the other hand, it is quoted in all three studies undertaken for this volume. In the latter studies, the observed last occurrences are located at significantly different levels, which differ from the one proposed by Simmons et al. (1996). In fact, the latter authors quote *G. elevata* s. s. from only two samples; the corresponding distribution is thus poorly constrained and they advise to define the taxon better before using it as a key index fossil for the location of the boundary.

In short, previous studies had shown that planktonic foraminifera were present in the succession at Tercis but also that useful information, if actually present, still remained to be obtained. That task was undertaken with patience and determination by J. Ion on the one hand while, in 1996, a new request for study was received from Spain and a second study was undertaken independently by J. Arz and E. Molina. This chapter will show both that the succession is able to deliver valuable information and that the independent studies led to fruitful complementary data.

2. Sampling, presence, abundance, preservation

The study of the planktonic foraminiferal content of the Tercis succession required a particular approach for better efficiency. Because of the generally hard nature of the deposits, a systematic study of samples taken at regular intervals could have been achieved only by using thin sections. However, the preliminary study had shown that such sediment is too poor in specimens for this single approach to be efficient. About 350 thin sections were observed at Paris; their usual content is 1 to 2 sections of globotruncanid per cm²; locally there is only 0.5 but more commonly there are 2 and up to 3 specimens per cm². Therefore, sampling was first restricted to most of the irregularly distributed disaggregable levels. These levels allowed to obtain large numbers of the specimens which were necessary due to the scarcity of biostratigraphically diagnostic forms versus those having a long range. The study of washed residues was supplemented later using thin sections locally prepared in large numbers for the search of

diagnostic forms (especially between levels 40 and 70). This combined approach led to document the succession with taxa observed both as free forms and as sections; comparisons with successions investigated using only the one or only the other of these two techniques will be favoured. In short, the study of the foraminifera was conducted in several steps, new sampling being repeatedly gathered when the previous observations left too large portions of the succession without information.

3. Diversity of the fauna, presence of key markers

3.1. Diversity of the fauna

The preliminary study (chap. C5a) led to the identification of 24 forms (including some diagnostic ones such as *Gt. elevata*, *G. falsostuarti*, *G. aegyptiaca*, *Rd. subspinoso*) picked from 26 washed residues. The quantitative study by Arz & Molina (chap. C5b) considered 31 washed residues; 60 different species were identified and the level assemblages comprised from 14 to 48 species. The qualitative study by Ion & Odin (chap. C5c) considered about 200 samples 40 of which could be disintegrated; the total number of identified forms is high (94) and the richest assemblages (about 40 forms) were observed in the Campanian-Maastrichtian boundary interval.

The combined list of taxa is given as Appendix 1 of this chapter. Several forms have probably been identified under different names by the different experts but this fact would not considerably diminish the total number of 125 forms quoted in this appendix.

3.2. Presence of key markers

The most important question about key markers concerns the presence of *Rd. calcarata* at Tercis and in the Aturian Basin. J.-P. Bellier did not recognise the presence of *Rd. calcarata* at Tercis and argued that the environment was not favourable to this open marine species (pers. com. 1993). The same was true for the section in the Baie de Loya, near Hendaye in the Pays Basque (absence of diagnostic planktonic foraminiferal forms, accord-

ing to J.-P. Bellier in Le Callonec et al., 1997). Ward and Orr (prelim. manuscripts and oral communication, Brussels, 1995) first supported the idea that *Rd. calcarata* was present at Tercis in the form of dissociated spines of shells in the washed residues; they later reinterpreted these spines as possibly coming from *G. (Rd.) subspinoso* (Ward & Orr, 1997). Simmons et al. (1997) failed to find the taxon and also argued that the environment (shallow water) and palaeogeography (embayment) was not favourable although the taxon was present in the nearby open Ocean, 900 km NW of Tercis, as concluded from its common occurrence in Campanian sediments collected from an oceanic drill (DSDP leg 48, hole 401; Dupeuble, 1978). Arz & Molina (chap. C5b) did not observe the taxon in the washed residues of their first sampling.

However, in the past *Rd. calcarata* was quoted from sediments deposited in the Aturian Basin. Destombes and Marie (1947) quoted the presence of *Rosalinella calcarata* (Cushman) in washed residues of subsurface samples (blue-grey marls) collected from a drilling at Peyrehorade (15 km S of Tercis, "près de l'hippodrome" - near the racecourse). Commenting upon this paper, S. Gubler reported that *Globotruncana (Radotruncana) calcarata* denoted high Campanian deposits and that it was previously quoted from the area in the Soust section as well as at Hendaye by J. Kikoïne (probably the Baie de Loya section, about 60 km SW of Tercis). Bartenstein (1948) quoted the taxon in a drilling at Saint Marcet (10 km N of Saint Gaudens, 160 km ESE of Tercis). Therefore, the species was swept into the northern pyrenean Aturian Basin far to the East (figure 1). Bartenstein quoted the interest of this short lived species for Europe-America correlation (it is present in the Gulf Coastal Province but absent from Western Interior) as well as toward the East in Caucasus, Ukraine; he also emphasised the easy identification of the form. As for us, we ourselves observed a microfossil separate (washed residue) with about 20 specimens of *Rd. calcarata* showing large spines which had been picked from sample GA 39 collected by Dars (1949). These specimens are illustrated in the plate. GA 39 is a surface sample which comes from the locality Brana, 2.5 km NW of Orthez (less than 30 km SE of Tercis). Sacal &

Debourle (1957) also quoted the taxon from Lasseube (12 km ENE of Oloron, North of the Pyrénées, 75 km SE of Tercis). Therefore *Rd. calcarata* was present in the Aturian Basin. If the palaeogeographic synthesis of Bilotte et al. (this volume, chap. A4) is correct, all the above-quoted aturian occurrences are located out of the pithonellid-bearing limestone (or aturian facies) and pertain to the slightly deeper North Pyrenean flysch facies (generally marls).

In spite of these known occurrences, the global distribution of the taxon shown by Kennedy et al. (1995) and taken from Masters (1977) essentially restricts its presence to two domains the Gulf Coastal province (North America) and the Greater Antilles, and South Central Europe, Italy, Tunisia with three small areas in Central Atlantic, Israel, and between N Madagascar and South Africa. The recent global distribution published by Puckett and Mancini (1998) is more exhaustive and shows additional presences in the Aturian Basin, South

Spain, the East coast of South America and, above all, Central Pacific which really makes the taxon a global key marker (figure 4 in Odin, this volume, chap. F2).

The presence of *Rd. calcarata* from the platform facies of the Aturian Basin (at Tercis) was affirmed in September 1995 (fax communication of Jana Ion to G.S.O. during the Brussels meeting). About half a dozen of specimens were later documented with pictures (identification J.I. on selected thin sections proposed by G.S.O., confirmation and photo by M.C.). They were photographed from levels 47.2 to 61.0, which was thus the minimum range of the taxon. Specimens referred to the taxon have been suspected below, down to level 3.8 and above, up to level 86.5 but, according to one of us (M.C.) the lowest occurrences are extremely weakly documented and no convincing forms were observed in the two young samples at levels 74.0 and 86.5. The continuous presence initially suspected from thin sections by one of us (J.I.) was between levels 41.1

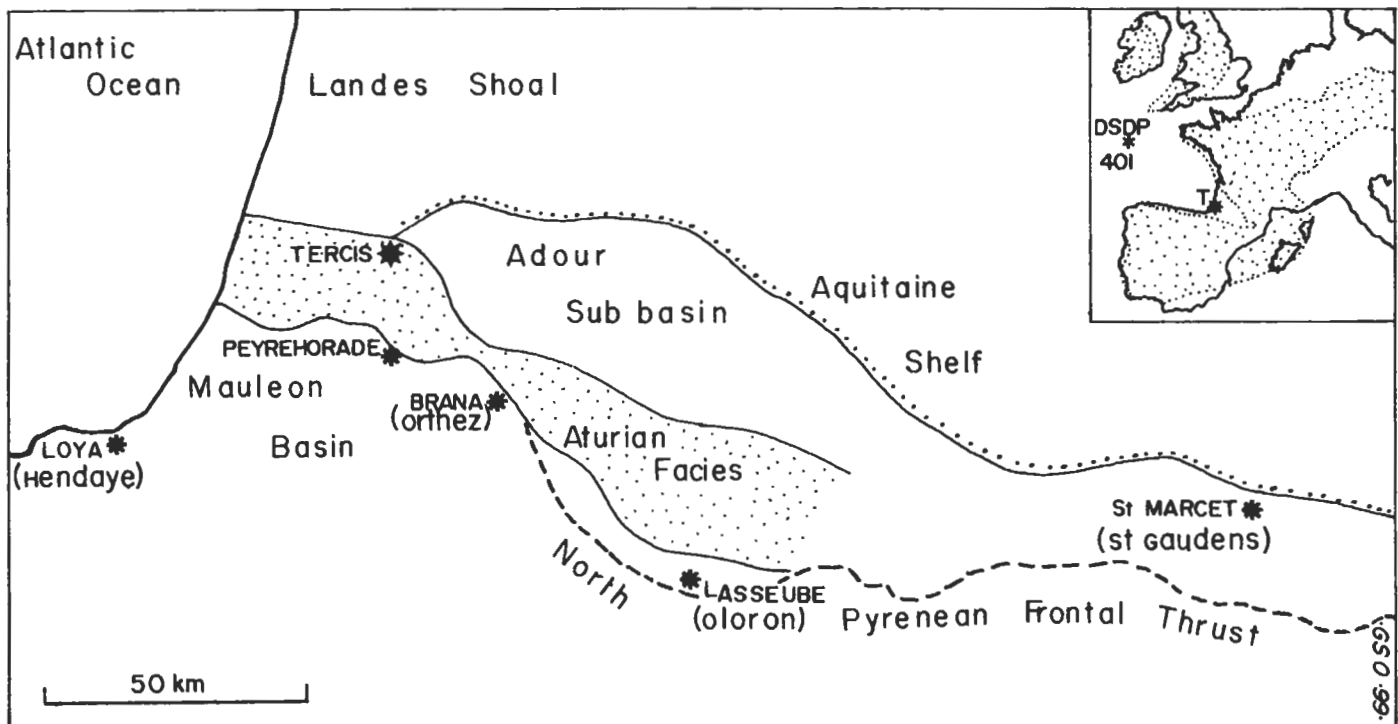


Fig. 1. Known occurrences of *Rd. calcarata* near Tercis in the Aturian Basin: Baie de Loya (Hendaye), Peyrehorade ("près de l'hippodrome": next to the racecourse), Soust section, Brana (2.5 km NW of Orthez), Lasseube (near Oloron), Saint Marcet (oil drilling near Saint Gaudens). The taxon was only known from the North pyrenean flysch facies but some occurrences are very near the pithonellid-bearing aturian facies. The nearest known occurrence of *Ab. mayaroensis* in Hastings is also shown (palaeogeographic scheme after Bilotte et al., this volume, chap. A4). Insert in the upper right corner shows the relative position of Tercis and DSDP hole 401 where *Rd. calcarata* is abundant.

and 61.0. The distribution was later supplemented with about 10 additional specimens between levels 39.5 and 62.0; sections are not diagnostic for sure out of this interval.

The representativity of the *Rd. calcarata* TRZ identified from Tercis can be discussed in the light of the estimated duration of deposition represented by the *calcarata*-bearing beds. The minimum range and continuous presence is 22.5 m thick (39.5–62.0) and the maximum, questionable, range (level 3.8 to 86.5) would be 80 m thick. If one uses the mean deposition rate of 1 m/40 ka favoured in this volume, the equivalent time intervals calculated for these two thicknesses would be 0.9 and 3.2 Ma respectively for the minimum and continuous, and the maximum questionable ranges.

Premoli-Silva & Sliter (1994) locate the TRZ between their metres 288 and 298 (about 10 m thick) in the Apennines where they observed the taxon in thin sections. They suggest a mean rate of sedimentation after compaction of 9.4 m/Ma for the Campanian, which means that their *Rd. calcarata* TRZ would be about 1 Ma long. Robaszynski & Caron (1995) show this zone about 1 Ma long. Li & Keller (1998) show the TRZ between 74.8 and 74.0 Ma or so in their study of the Tunisian Campanian-Maastrichtian succession. It is not always clear how well these estimates have been calibrated and how accurate they are. However, the usual estimate for the duration of the *Rd. calcarata* TRZ is about 1 Ma and the continuous distribution documented by us perfectly coincides with this estimate. Although this could be seen as a partly circular reasoning (sedimentation rate, rarity of observations of the taxon at Tercis), it is suggested that the whole life interval of the taxon is recorded at Tercis between about level 39.5 and level 62.

Other useful key markers are quoted in figure 2 and 3. We may also remember that, higher up in the succession, *Ab. mayaroensis* has been quoted from a thin section by J. Ion. This taxon is known from the Aturian Basin and we have personally observed a cell noted "*Ab. mayaroensis* (coll. Elouard, SE d'Hastings)" in Madeleine Neumann's former collection. The village of Hastings is located a few km W of Peyrehorade (less than 20 km S of Tercis) and thus the taxon is present in the Aturian Basin near the domain of the aturian facies.

4. Stratigraphy

4.1. Continuity of the succession

Environmental changes and/or possible breaks in the continuous sedimentation in the Aturian Basin can be suspected from the possible breaks in the distribution of the taxa (contemporaneous first occurrences (FOs) and last occurrences: LOs).

Ion & Odin recognise five faunal arrivals: at levels 11.4 and 13.7 (about 10 new species each), at levels 39.5 to 41.1, at levels 74.0 to 80.2 (about 5 species), at level 97.2 (about 6 new species), at level 117.8. The first major arrival, in the lower portion of the d'Avezac Unit, is essentially due to a better sampling. The second arrival is not abrupt: new forms are observed at level 39.5, others at 40.45, others at 41.0. No LO corresponds to these FOs. The third arrival is progressive, centred on two samples collected at levels 76.0 and 77.2, and interestingly comprises the FOs of the two new species proposed by Ion (*G. aturica* and *Gtl. tercensis*). The fourth arrival at level 97.2 is clearly connected to the availability of an easily disintegrated sample with a rich fauna (37 taxa). The fifth arrival presents the same character: level 117.8 is the richest of the succession and this corresponds to the FOs of a few taxa including two key ones (*Ct. contusa* and *Gt. stuarti*); two LOs occur nearby, that of *Gtl. tercensis* immediately below and that of *G. rosetta*–*Gtl. insignis* immediately above.

The distribution given by Arz & Molina also shows the above 3rd event with seven taxa including several *Rugoglobigerina* appearing in their sampled levels 73.9, 76.1, 79.4. Around point above, two apparent FOs occur (*R. pennyi* and *Gt. stuarti*); but the former is quoted spotty below by Ion & Odin and the latter is only quoted from much higher in the series by the same authors); the faunal change is small. Point 5 (level 116.8 in Arz & Molina) corresponds to three FOs (*Gublerina acuta*, *Ct. walfischensis*, *Rg. scotti*); the location of the second marker is in agreement with that given by M. Caron but J. Ion also quotes the taxon from many older levels.

In short, no important sedimentary break can be evidenced by a corresponding break in the distribu-

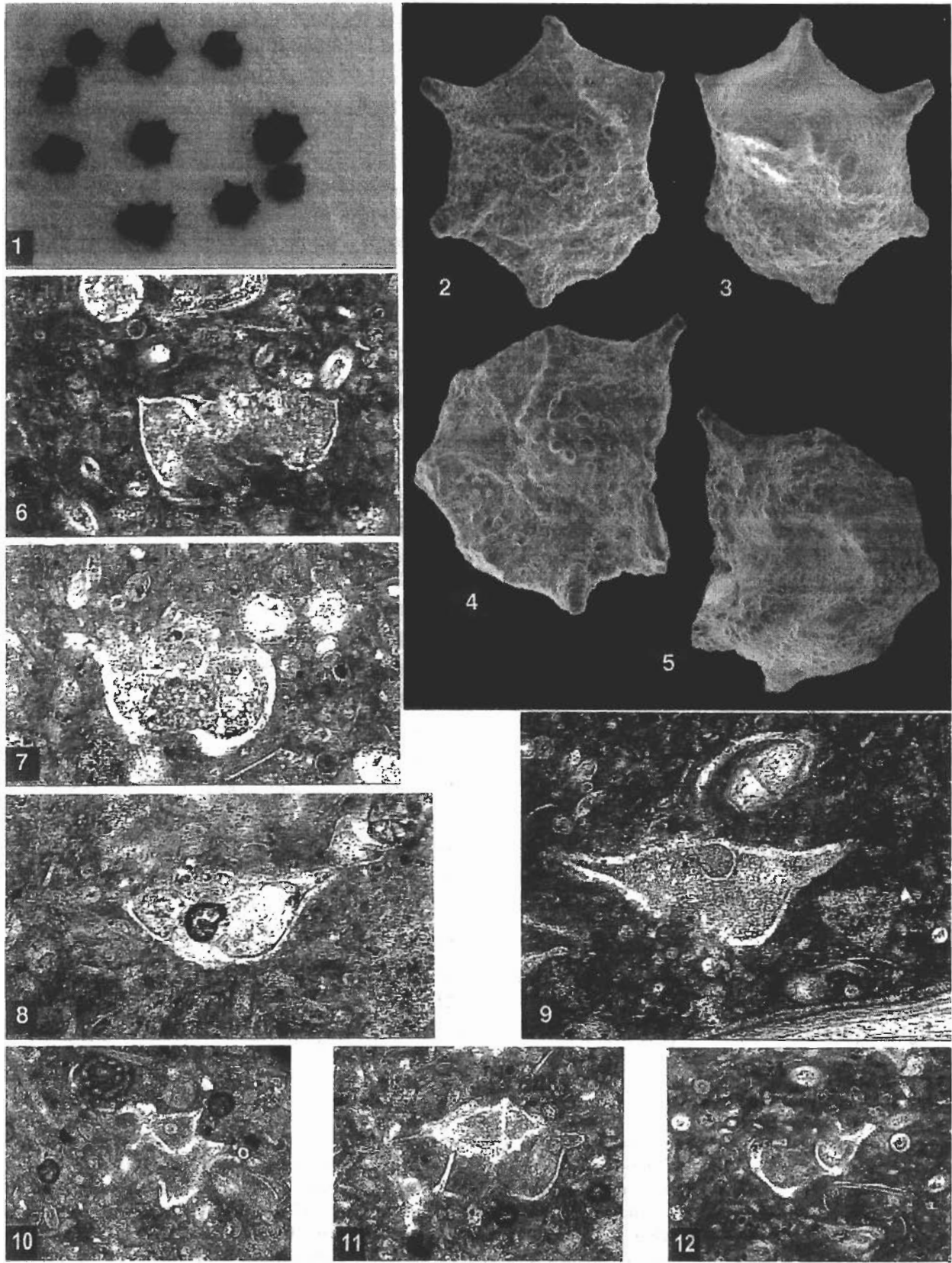


Plate I: Selected views of *Rd. calcarata*. 1 to 5: specimens from Orthez; 1: enlarged x15; 2 & 3: spiral and umbilical side; 4 & 5: spiral and umbilical side; 6 to 12: thin sections from Tercis; 6: II 61.0- O1; 7: II 47.2- O1; 8: II 52.0- O2; 9: II 55.0- O1; 10: II 39.5- A; 11: II 62.0- A1; 12: II 62.0- B2. Pictures by M.C. in Friburg; 2 to 9: enlarged x100; 10 to 12: enlarged x50. All x0.8 in printing.

tion of the taxa along the studied portion of the Tercis succession.

4.2. Species distribution

Figure 2 summarises the data obtained on selected taxa by the different experts. Potential events will be discussed below considering first, the taxa

identified by several experts and second, the taxa identified by a single expert.

The LO of *Gt. elevata* is shown by Simmons et al. (1996) as occurring within Unit N1, which may correspond either to our level 115 or to our level 125 (Odin, this volume, chapter B1a); the latter authors emphasise the interest of this taxon for correlation of the Campanian-Maastrichtian boundary. Caron and Arz & Molina see a distribution

Authors	Caron & Odin	Arz & Molina	Ion & Odin	Conclusion
Processing	washed residues	washed residues	residues+sections	
LO <i>Globotruncanita elevata</i>	14.8-20.8 (39.5)	11.5-22.7	131.4-135.8	determination ?
LO <i>Marginotruncana marginata</i>	20.8-30.1	22.7-39.6	14.8-15.8	26.4 ±3.7
LO <i>Marginotruncana undulata</i>	n.d.	22.7-39.6	n.d.	about 31
FO <i>Heterohelix glabrans</i>	n.d.	22.7-39.6	n.d.	31 ±9
LO <i>Globotruncanita atlantica</i>	n.d.	39.6-64.8	39.5-40.5 (97.2)	40.0 ±0.5
FO <i>Radotruncana calcarata</i>	n.d.	n.d.	(*a)40.5-41.1	about 39.0 (*b)
LO <i>Marginotruncana sinuosa</i>	?48.7-64.8?	39.6-64.8	48.7-49.8	(49.2 ±0.6)
LO <i>Radotruncana calcarata</i>	n.d.	n.d.	62.0-62.9	about 62.5 (*b)
FO <i>Globotruncanella havanensis</i>	n.d.	39.6-64.8	61.9 (spotty)	51 ±11
FO <i>Globotruncana aegyptiaca</i>	110.0 (spotty)	39.6-64.8	11.4-13.7	determination ?
FO <i>Globotruncanita angulata</i>	?95.6	73.9-76.1	51.0-52.0	64 ±12
FO <i>Globotruncanella petaloidea</i>	n.d.	73.9-76.1	n.d.	about 75.0
FCO <i>Globotruncana falsostuarti</i>	64.8-76.0	73.9-76.1	(*c) 74.0-76.0	75.0±1.0
FO <i>Rugoglobigerina hexacamerata</i>	n.d.	73.9-76.1	?97.2	about 75.0
FO <i>Rugoglobigerina rotundata</i>	n.d.	76.1-79.4	97.2 (spotty)	about 77.7
FO <i>Rugoglobigerina macrocephala</i>	n.d.	76.1-79.4	n.d.	about 77.7
FO <i>Contusotruncana plicata</i>	n.d.	79.4-89.4	cf. 97.2	determination ?
FO <i>Globotruncanita stuarti</i>	n.d.	89.4-95.7	117.8 (spotty)	about 93
FO <i>Contusotruncana contusa</i>	cf.117.8-119.9	(109.5) 115.7-116.8	116.2-117.8	116.5 ±0.3
FO <i>Contusotruncana walfischensis</i>	116.2-117.8	115.7-116.8	47.2-48.7	determination ?
FO <i>Rugoglobigerina scotti</i>	n.d.	115.7-116.8	n.d.	about 116.2
FO <i>Gansserina gansseri</i>	n.d.	? 170-172	n.d.	? 171 (delayed)
LO <i>Contusotruncana fornicata</i>	> 160	155.1-161.5	> 174	above quarry

Fig. 2. Location of the biostratigraphic signals identified in the different studies.

The location is generally given in the interval between two successively studied samples. *a- specimens were quoted at levels?3.8 and 13.7 by Ion; *b- specimens were quoted at levels?62.0 and 86.5 by J. Ion and a new series of thin sections prepared in 1999 documented the presence between levels 39.5 and 62.0; *c- the FO is at or below level 15.8. according to Ion. We could not obtain convincing photos of *Rd. calcarata* from below or above the FO and LO quoted in the figure. Levels shown in brackets indicate isolated occurrences; question marks note problems in the identification. The distribution is not considered well established when the occurrences are rare (shown as "spotty"). The column conclusion combines the different data. When based on a single observation the conclusion is given as approximate (≈). Large differences in the observation suggest a problem of taxonomic definition or poor preservation. Key signals are shown in bold print.

consistently ending between levels 14.8 and 20.8, with a questionable specimen at level 39.5; the LO could thus be located at level 17.8 ± 3.0 . However, Ion identifies "typical forms" of *Gt. elevata* at level 119.9 and up to level 131.4 (see chap. C5c: photo 96 to 98, and appendix to C5c). There is possibly a taxonomic problem with this form which should be used with care for correlation; the interval between the same signal seen by the different experts (125 metres) represents something like 5 Ma in the Tercis succession.

The LOs of different species of the genus *Marginotruncana* give reproducible signals in the d'Avezac Unit at Tercis (figure 2).

According to Ward & Orr (1997), the LO of *G. atlantica* would be at level 105. Arz & Molina see the same signal between their samples 39.6 (present) and 64.8 (absent). The distribution by Ion may appear consistent with a LO between levels 39.5 and 40.5 but for a single isolated occurrence at level 97.2 (all the specimens were observed in washed residues). The LO located at 40.0 ± 0.5 probably represents a last common occurrence in the light of the isolated presence of typical forms above (see chap. C5c: photo 94, 95, and appendix).

The FO of *G. aegyptiaca* is inconsistently constrained in the three studies. M. Caron did not find many specimens in her preliminary study. Arz & Molina suggest a continuous presence above level 64.8, but J. Ion shows a spotty occurrence below (both in washed residues and in thin sections) with a number of questionable specimens. The presence of the taxon at Tercis seems to be established from level 64.8 upwards (thus very near the top of the *Rd. calcarata* TRZ at level 62.0). The isolated occurrence at level 14.8 comprises typical specimens according to Ion (see chap. C5c: photo 52, and appendix). A problem of determination probably exists for this species if one notes that neither Ward & Orr (1997), nor Simmons et al. (1996) quote a taxon found by all our experts, and that the FO of this taxon is usually taken as a key for locating the base of a Zone located above the TRZ of *Rd. calcarata*; in the Bottaccione section, the FO of *G. aegyptiaca* is located 12 m above (or about 1.2 Ma younger than) the LO of *Rd. calcarata*. If our observations are accepted, the

"classical" *Gt. havanensis* zone defined as the interval between the LO of *Rd. calcarata* and the FO of *G. aegyptiaca* does not represent a significant interval of time and could be questioned as a valid zone in the Aturian basin.

The FO of *Gt. angulata* is quoted by Ward & Orr (1997) at level 155. The three present studies indicate a reasonably reproducible oldest occurrence. M. Caron notes questionable specimens from level 97.2 up. Arz & Molina see the taxon rather continuously from level 76.1 upward. Jana Ion quotes it at and above level 52.0 and with a cf. specimen below. The FO is thus imprecisely located between levels 52 and 76 (or 64 ± 12) and probably in the lower portion of this interval.

The FO of *G. havanensis* is mainly documented by Arz & Molina with a continuous presence above level 64.8. However, the FO can only be located in the interval 52 ± 13 for sampling reasons. Jana Ion has seen the taxon in a single washed residue at level 76.0. Therefore, the FO is uncertainly constrained but the taxon exists in the higher half of the d'Avezac Unit.

The FO of *G. falsostuarti* is located between levels 64.8 and 76.0 by Caron. Arz & Molina consistently show its FO between levels 73.9 and 76.1. Ion sees the taxon spotty at levels 15.8 and 40.5; specimens from level 15.8 seem to be typical of the taxon (see chap. C5c, photo 37, 38, and appendix). However, a more continuous presence is observed from between levels 74.0 and 76.0 up to the top of the succession in the quarry.

Jana Ion has quoted intermediate forms that mark the evolutionary trend to *G. falsostuarti*. i- a taxon noted as intermediate form between *G. arca* and *G. falsostuarti* is found at level 11.4 (see Ion, chap. C5c, photo 36) and then from level 80.2 up to the top of the succession in the quarry; ii- *G. sp. 1* (n. sp.?) and the intermediate form between *G. sp. 1* and *G. falsostuarti* have both their FO at level 14.8 (see Ion, chap. C5c, photo 32 and 39 respectively); these three taxa appear slightly below *G. falsostuarti* and they co-occur later with typical forms; iii- a taxon noted as intermediate form between *G. orientalis* and *G. falsostuarti* represents an ecophenotypic variant of the evolutionary trend of *G. falsostuarti*; it is quoted from levels 77.2 and 86.5 in co-occurrence with typical *G. falsostuarti*.

From the many diagnostic features brought to our knowledge above, it seems clear that the FO of *G. falsostuarti* can be located as low as level 15.8. We also suggest a reproducible first continuous occurrence (FCO) at level 75.0 ± 1.0 . *G. falsostuarti* is sometimes considered typical of the Maastrichtian stage but it is also considered present in the upper Campanian by Sigal (1977 in the mesogean area), by Caron (1985, in west European domain), and by Ion (in Ion et al., 1997a in Rumania). The FO of *G. falsostuarti* is slightly older than the FO of *G. calcarata* in Tercis in agreement with the observations in the Apennines where it is present but rare 2 m below (or about 200 ka older than) that latter form (Premoli-Silva & Sliter, 1994).

The FO of *Ct. plicata* at level 89.4 (Arz & Molina) can be compared with the FO of the intermediate form *Ct. plummerae-Ct. plicata* observed at level 97.2 by J. Ion. For this latter author, typical forms are only present in sections E and B from level ≈ 163 upwards. There is probably a taxonomic problem to be solved for this species at Tercis.

The FO of *Gt. stuarti* is quoted by Ward & Orr (1997) from level 90. Arz & Molina precisely confirm this observation with a FO in the interval 89.4–95.7 at the top of the d’Avezac Unit. J. Ion quotes a single occurrence in the main outcrop at level 117.8.

Ct. contusa is given by Ward & Orr (1997) as appearing at the base of the Bédât section (level B–40 \approx level P 230). M. Caron quotes intermediate forms between *Ct. patelliformis* and *Ct. contusa* (FO: between levels 117.8 and 119.9); this corresponds to the observation of *Ct. contusa* by J. Ion (FO: 116.2–117.8). Arz & Molina observe the repeated presence of *Ct. contusa* for 20 metres above level 116.8 with a single presence below at level 109.5. We suggest to locate the FO of *Ct. contusa* between level 116.2 where it is absent and level 116.8 where it is present (i.e. 116.5 ± 0.3). This signal is of great interest as the best proxy for the Campanian-Maastrichtian boundary; it seems of wide value for the Tethyan domain.

The FO of *Gs. gansseri* is quoted by Ward & Orr (1997) at level 155. M. Caron notes that the actual *Gs. gansseri* morphotype is absent from her separates but that intermediate forms identified as

Gt. insignis?/angulata? are present from level 116.2 to 160 and can be morphologically interpreted as an index suggesting that *Gs. gansseri* might occur nearby. Jana Ion quotes the oldest *Gs. gansseri* from the E section at level E 57.7 (or \approx P 172). According to Ion (chap. C5c), *Gt. insignis?/angulata?* of Caron is the new taxon *Gtl. tericensis* which occurs commonly from level 77.2 to level 116.2 and spotty above up to level B–24.8 in the Bédât Unit. *Gs. gansseri* is rare; from the presence of other micro- or macrofossils such as ammonites or nannoflora, the FO of *Gs. gansseri* at Tercis seems significantly delayed compared to its FO in the Apennines. The local level of the FO cannot be used with confidence for global correlation (nor zonal subdivision); but further studies should look for the presence of *Gt. angulata* which is extremely difficult to distinguish from *Gs. gansseri* in thin section (personal communication F. Robaszynski, June 2000).

The LO of *Ct. fornicata* is shown in Unit O (level 135 or 145) by Simmons et al. (1993). Ward & Orr (1997) locate it at the base of the Bédât section (\approx level 230). The three studies in this volume agree that it is located above the levels sampled in the quarry.

Let us consider now the taxa quoted by a single expert. There are several reasons why interesting taxa have been considered by a single expert: i- scarcity, ii- focus of the study, iii- methodological approach. *Rd. calcarata* is relevant to points i and iii: it seems that only thin sections are able to document this taxon in the hard limestone where it is present. Many thin sections were prepared from the potentially productive beds in addition to the systematic sampling which had been initially collected every two to three metres. The genera *Rugoglobigerina* and *Heterohelix* are relevant to point ii: only Arz & Molina make more specific determinations. In spite of the single quotation of these taxa, they are key ones for the correlation of the Tercis section with other depositional basins.

The FO and LO of *Rd. calcarata* have been initially documented by J. Ion. New samples collected in September 1998 lead two of us (J.-A.A. & E.M.) to identify three specimens of the taxon from a washed residue of level 58. The preservation is good with spines mostly preserved. From a

hundred additional thin sections prepared in 1999, the presence of the taxon is now documented between levels 39.5 and 62.0 (M.C. & G.S.O.).

The FOs of *Heterohelix glabrans*, *Rugoglobigerina hexacamerata* and *Rg. rotundata* are key markers for Arz & Molina. For sampling reasons, the two former are still poorly constrained in the lower part of the d'Avezac Unit. It is worth noting that J. Ion has suspected a nearby morphotype quoted as intermediate form *Rg. rugosa*–*Rg. hexacamerata* occurring at levels 97.2? and 117.8. Even more interesting is the FO of *Rg. scotti* (at about level 116.2) which, according to Arz & Molina, is the best planktonic foraminiferal proxy for the location of the Campanian-Maastrichtian boundary.

As a final remark, we wish to note that the 14 signals quoted in figure 2 above the LO of *Rd. calcarata* are all first occurrences as if the end of the Campanian and earliest portion of the Maastrichtian was a period of significant speciation during which previous forms were able to survive and share the available space of life with newly established forms.

4.3. Biozonation at Tercis

Figure 3 shows the location of the main signals observed in the succession sampled in the quarry (main outcrop and E section). Seven primary markers are shown together with six secondary ones. The vertical uncertainty for their location results from the comparison of the data obtained by different experts and no uncertainty is given when the marker has been considered by a single expert (this does not mean that the location of the corresponding signal is better known). The zonal subdivisions proposed by the different experts are shown on the right.

Arz & Molina propose six zones for the deposits of the d'Avezac and the Les Vignes Unit outcropping in the quarry. However, the FOs of four of the diagnostic forms which are taken to define the base of four of these zones are either not known with a better precision than the thickness of the zone itself (*H. glabrans* and *Gl. havanensis*) or documented by a single study (thus the reproducibility cannot be estimated) and so near each other (FO of *Rg. hexacamerata* and FO of *Rg. rotundata*)

that the beginning and end of the zone are virtually contemporaneous. In short, the search for more subdivisions leads to non reproducible zones.

Ion proposes three zones, the youngest being subdivided into three subzones. The number of subdivisions is about similar to the previous proposal but the larger number of samples studied allows to determine the limits with greater precision. No characteristic fossil is suggested for the (Campanian) first "X Subzone" of the *G. falsostuarti* Zone. The *Ct. contusa* subzone can be discussed: the lower limit is defined by the FO of this taxon; however, Arz & Molina have quoted a specimen at level 109.5. The upper limit is defined by the FO of *G. esnehensis*, high in the dark-flint-bearing portion of the Les Vignes Unit; however, the fauna of this portion of the succession (above level 136) is poor with only 5 to 10 species identified, so that the signals observed there are not well documented.

As shown in figure 3, a combined scheme with four zones can be suggested. Due to insufficient sampling, it is not yet possible to document the correctness of the equivalence between the *Rd. calcarata* TRZ and the *H. glabrans* Zone used by Arz & Molina. But the contemporaneity of the FOs of these two taxa is possible at Tercis and would be in agreement with what has been observed in Spain. The unnamed "X Subzone" of J. Ion can be identified as follows: if one considers the presence of the *Rd. calcarata* Zone below, the fact that *Gl. havanensis* locally appears either in the former zone or at the top, and the fact that *Rg. rotundata* appears in the lower part of the "X subzone", it is proposed here to create a *Gl. havanensis*–*Rg. rotundata* zone in place of the "X subzone" of J. Ion. Its lower limit would be defined at the LO of *Rd. calcarata* and in presence of *Gl. havanensis*. Its upper limit at Tercis would be located where *Rg. scotti* and *Ct. contusa* first occur together. A combination of the two taxa (a globotruncanid and a globigerinid) seems to be necessary when using this scheme for correlation because the forms called *Ct. contusa* seem to appear at different time-levels according to the literature (see below) and the quotation of *Rg. scotti* is a useful additional criterion for a better chronological constraint. The upper limit of this *Rg. scotti*/*Ct. contusa* zone

cannot be defined in the Tercis Quarry (the fauna is poorly documented at the top).

It is to note that *Gl. havanensis* is used in other areas to designate the next biozonal unit above the

calcarata TRZ. The *Gl. havanensis* zone (defined as the interval between the LO of *Rd. calcarata* and the FO of *G. aegyptiaca*) is distinct from our *havanensis-rotundata* zone of Tercis at its top.

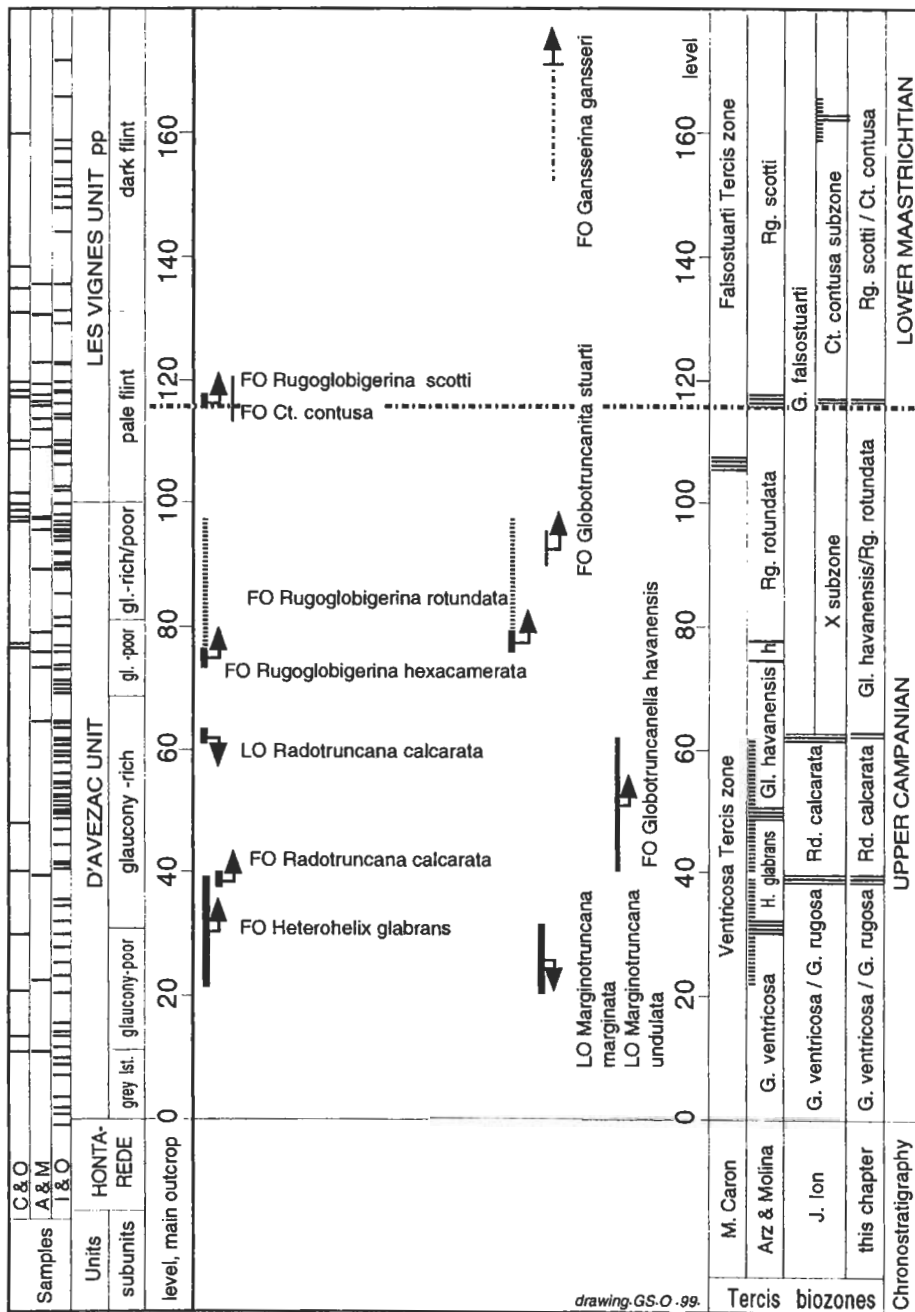


Fig. 3. Planktonic foraminiferal biostratigraphic markers observed in the succession at Tercis (levels exposed in the quarry). The location of the samples studied in each of the three studies are shown on the left. About 100 additional thin sections were prepared in 1999 from the restricted intervals at the bottom and top of the distribution of *Rd. calcarata*. The zonal schemes based on the material found at Tercis are shown on the right. The uncertainties of the zonal limits are estimated from the sampling. Note that between the *Gl. havanensis* and the *Rg. rotundata* zone of Arz & Molina, there is a thin *Rg. hexacamerata* zone.

4.4. Comparison with the known foraminiferal record from other areas

Premoli-Silva & Sliter (1994) note "the strong decrease in abundance and then extinction of the last marginotruncanids near the middle of the *Globotruncana elevata* Zone" in the Bottaccione section of the Apennines. However, their table of distribution shows specimens of *Margino-truncana sigali*, ?*M. pseudolinneiana*, and *M. coronata* up to their level 280: i.e., 8 metres below the FO of *Rd. calcarata* (and the limit between the *ventricosa* and the *calcarata* Zones). In Tercis all experts have found several species of marginotruncanids up to the upper portion of the *G. ventricosa* Zone and one species (*M. sinuosa*, absent in the Apennines) reaching the lower portion of the *Rd. calcarata* Zone. *M. sinuosa* has been found either dubious or extremely rare by all experts at the top of its range and the apparent LO (level 49.2 ± 0.6 , figure 2) is more uncertain than would suggest the calculated uncertainty; in fact, marginotruncanids essentially disappear immediately below or in correspondance with the FO of *Rd. calcarata*.

The zonal names *G. ventricosa* (or *G. rugosa*) and *Rd. calcarata* used in figure 3 are used in other areas and are assumed to cover similar intervals of time at Tercis, as discussed above for the occurrence of *Rd. calcarata*.

Our *Gl. havanensis*-*Rg. rotundata* zone most probably covers the same interval of time as the *havanensis* zone used in other areas (see zonal schemes by Caron, 1985; Robaszynski & Caron, 1995) at the bottom but it probably also comprises a portion (or all) of the *G. aegyptiaca* zone and possibly a petty portion of the *Gs. gansseri* zone used elsewhere at the top. In Tercis, the FO of *G. aegyptiaca* has not been precisely recognised since the taxon has been diversely located in the succession by the different experts (surprisingly, including in levels below the *Rd. calcarata*-bearing deposits). The early occurrence of *G. aegyptiaca* is known from other areas of the Tethys too; it co-occurs there with *Rd. calcarata* (Ion, 1983; Ion in Ion et al., 1997a, in Rumania; Almqy-Labin et al., 1986, in Israel).

Gs. gansseri is rare at Tercis and its FO has been intercepted higher than the FO of *Ct. contusa*. The

latter has generally been observed significantly above the former in other basins; it is observed slightly above in Tunisia, (9 m, Li & Keller, 1998) but much higher in the Apennines where it is shown to appear together with *R. fructicosa* (Premolisilva & Sliter, 1994). Robaszynski & Caron (1995) show the FO of *Ct. contusa* to be about 3 Ma younger than that of *Gs. gansseri* in their table but their comment is that "*Ct. contusa* apparaît en même temps ou très légèrement après *Gs. gansseri*" (p. 689). *A contrario*, these observations suggest that the (comparatively early) FO of *Ct. contusa* at Tercis is low in the total range of that species and this low local FO can be reasonably interpreted as an evolutionary FO or inception of good potential for correlation. The FO of *Ct. contusa* at the base of the Maastrichtian is documented from Crimea where it is shown to be contemporaneous with the FO of the belemnite *Belemnitella lanceolata* (Alekseev & Kopaevich, 1997).

Because of the scarcity of *Gs. gansseri* at Tercis, it has not been possible to verify the contemporaneity of the FO of this taxon with that of *Rg. rotundata* which is assumed by Arz & Molina; if correct, this assumption would suggest that the FO of *Gs. gansseri* at Tercis is delayed by about 95 metres (which would correspond to more than 3.5 Ma) compared to its evolutionary inception.

4.5. Comparison between ammonitic and planktonic foraminiferal control

We can give a few comments on the intercalibration of the ammonite record and the foraminiferal record for which the succession at Tercis is now becoming one of the best examples. According to Robaszynski & Caron (1995) the TRZ of *Rd. calcarata* is entirely located in the upper part of the *Bostrychoceras polyplacum* ammonite zone. However, Kennedy et al. (1995) note that "the extinction point of *Rd. calcarata* is above the extinction point of *B. polyplacum*; seemingly, even the lowest *Rd. calcarata* is above the highest *B. polyplacum*" at El Kef (Tunisia). At Tercis, T. Küchler (this volume, chap. D4e) identifies *B. polyplacum* between II 20.9 (n°341) and II 45.2 (n°9); the taxon is not very rare in this interval according to our observations *in situ* (G.S.O.; see also Ward & Orr, 1997). Our

documented distribution in Tercis is consistent with the suggestion by Kennedy et al. (1995), i.e., the major portion of the range of *B. polyplacum* is older than the range of *Rd. calcarata* and Tercis documents the first good relative record of these two key taxa which co-occur for about 0.2 Ma.

Higher up, the presence (TRZ) of *Nostoceras hyatti* and allied forms at Tercis can be regarded more or less contemporaneous with the upper 4/5 of our *Gl. havanensis-Rg. rotundata* zone (Odin, Courville et al., this volume, chap. D4g).

At the Campanian-Maastrichtian stage boundary, the limit between our *Gl. havanensis-Rg. rotundata* Tercis zone and our *Rg. scotti/Ct. contusa* Tercis zone coincides with the FO of a variety of ammonites including *Pachydiscus neubergicus* and *Hoploscaphites constrictus*. These are the most often quoted ammonites characterising the Maastrichtian. These ammonite FOs are usually correlated, in turn, to above the FO of *Gs. gansseri* (though with few known direct co-occurrences) this seems to document a delayed entry (or great scarcity at the beginning of its range) of this taxon in the succession at Tercis. Arz & Molina have already noted the contemporaneous FOs of *Rg. scotti* and of *P. neubergicus* in Spain and this good consistency mutually reinforces the chronological validity of the biosignals which are thus significant events at Tercis.

5. Conclusion

The study of the planktonic foraminifera of the upper Campanian-lower Maastrichtian succession at Tercis has been independently undertaken by different experts. The succession has been documented with a large variety of taxa; their identification used both thin sections and washed residues.

The combined list of taxa comprises 125 forms including new ones established for the first time in this volume by J. Ion. Among these forms, key taxa have been identified, though sometimes with difficulty. First order taxa include *Heterohelix glabrans*, *Radotruncana calcarata*, *Rugoglobigerina hexacamerata*, *Rg. rotundata*, *Contusotruncana contusa*, *Rg. scotti*. Additional useful forms include several species of *Marginotruncana*, *Globotruncanella havanensis*, *Globotruncanita stuarti*. Other

forms have a long range or a distribution which seems to be regionally dependent (*Gansserina gansseri*) or taxonomically insufficiently well defined (*Globotruncanita elevata*).

The most significant finding is the documentation of the presence and distribution of *Rd. calcarata*; the absence of this taxon was suggested in previous studies and commented on as a strong weakness of the Tercis section as a potential reference section for global correlation. Its now evidenced presence, documented again in this chapter, makes the proposed Tercis global stratotype section a well suited one.

The general distribution of the taxa seems to be consistent with the one observed in other outcrops; taxa are progressively appearing or disappearing; this indicates that no important depositional break occurred in the succession.

The vertical distribution allows to suggest a subdivision of the succession into four well documented biozones: i- the *G. ventricosa/G. rugosa* Biozone, ii- the *Rd. calcarata* total range Biozone (defined by the FO and LO of the taxon), iii- the *Gl. havanensis-Rg. rotundata* Biozone and iv- the *Rg. scotti/Ct. contusa* Biozone (the base of which is defined by the subcontemporaneous FOs of the two taxa). The biozone limits are placed at about level 39.0, about level 62.5, and about level 116.2 as noted in the main section (quarry fronts).

Another interest of the Tercis succession is that it allows to correlate the planktonic foraminiferal evolution directly with that of other fossil groups. For example, the major portion of the *Rd. calcarata* total range Biozone is younger than the *Bostrychoceras polyplacum* total range Biozone, the two zones are contemporaneous for only a few metres representing about 0.2 Ma. The *Nostoceras hyatti* zone (including allied forms, see K uchler & Odin, this volume, chap. D4e) is entirely below our *scottii/contusa* foraminiferal biozone, the base of which is subcontemporaneous with the FOs of *Pachydiscus neubergicus*, *Hoploscaphites constrictus* and of a few other ammonites known to be restricted to Maastrichtian formations. The Campanian-Maastrichtian boundary, as defined in this volume, is located very close to the biozone limit between our *havanensis-rotundata* Biozone and our *scotti/contusa* Biozone.

Although the studies have been so careful and time-consuming, additional research could improve our knowledge of the succession. In particular, the major portion of the Maastrichtian deposits which lies above the beds exposed in the quarry fronts could be fruitfully investigated.

Acknowledgements

As the Working Group chairman, G.S.O. is deeply indebted to the experts who accepted first to work independently on the material from Tercis and later accepted to objectively combine their observations. In addition, the significant results obtained in spite of a non ideal material has needed a welcome obstinacy of the experts who finally discovered a number of key specimens where others had failed. M. A. Lamaurelle and C. Estrada are greatly thanked for English improvement of the former version of this chapter. We all thank the past quarry owners (Calcia Division, Ciments Français Cy) who liberally gave permissions for repeated sampling in the quarry. The portion of this research by J. A. A. and E. Molina was funded by DGES project PB97-1016.

(Prepared: May 1999, improved: November 1999)

6. Appendix 1: Planktonic foraminifera from the geological site at Tercis (Landes, France)

The list of taxa is given in alphabetical order. Identification as proposed by M. Caron (C), by J. A. Arz & E. Molina (AM), and by J. Ion (I). Forms referred to "I*" are newly described forms (see Ion: Appendix 1 to chap. C5c).

Genus *Abathomphalus* Bolli, Loeblich & Tappan, 1957

Ab. mayaroensis (Bolli, 1951) by I

Genus *Archaeoglobigerina* Pessagno, 1967, emend. Robaszynski et al., 1984

A. blowi Pessagno, 1967 by AM, I

A. cretacea (d'Orbigny, 1840) by AM, I

Genus *Contusotruncana* Korchagin, 1982

Ct. contusa (Cushman, 1926) by AM, I

Ct. fornicata (Plummer, 1931) by AM, C

Ct. fornicata morph. A (Plummer, 1931) by I*

Ct. fornicata morph. B (Plummer, 1931) by I*

Ct. fornicata morph. B-*Ct. contusa* intermediate form by I*

Ct. manauensis (Gandolfi) by I

Ct. morozovae (Vassilenko, 1961) by I

Ct. morozovae-*Ct. walfischensis* intermediate form by I*

Ct. patelliformis (Gandolfi, 1955) by C, AM, I

Ct. patelliformis?/*contusa*? intermediate form by C

Ct. plicata (White, 1928) by AM, I

Ct. plummerae (Gandolfi, 1955) by AM, I

Ct. plummerae morph. *ackermanni* (= subsp. *ackermanni* Gandolfi, 1955) by I

Ct. plummerae-*Ct. plicata* intermediate form by I

Ct. walfischensis (Todd, 1970) by C, AM, I

Genus *Gansserina* Caron, Gonzales, Donoso, et al., 1984; in Robaszynski et al., 1984

Gs. gansseri (Bolli, 1951) by I

Gs. wiedenmayeri (Gandolfi, 1955) by I

Genus *Globigerinelloides* Cushman & Ten Dam, 1948 emend. Smith & Pessagno, 1973

Gb. multispinus Lalicker, 1948 by I

Gb. prairiehillensis (Pessagno) by AM

Gb. prairiehillensis (Pessagno) by AM

Gb. rosebudensis Smit and Pessagno by AM

Gb. subcarinatus (Brönnimann) by AM

Gb. volutus (White, 1928) by AM, I

Gb. yaucoensis Pessagno by AM

Gb. spp. by I

Genus *Globotruncana* Cushman, 1927 with emendations (see Robaszynski et al., 1984)

G. aegyptiaca Nakkady, 1950 by C, AM, I

G. aegyptiaca morph. *duwi* (= var. *duwi* Nakkady, 1959) by I

G. arca (Cushman, 1926) by C, AM, I

G. aturica n. sp. by I*

G. arca-*G. falsostuarti* intermediate form by I*

G. bulloides Vogler, 1941 by C, AM, I

G. dupeublei Caron et al., 1984 (in: Robaszynski et al., 1984) by I

G. esnehensis Nakkady, 1950 by I

G. falsostuarti Sigal, 1952 by C, AM, I

G. hilli Pessagno, 1967 by I

G. lapparenti Brotzen, 1936 by I

G. lapparenti morph. Y by I*

G. linneiana (d'Orbigny, 1839) by C, AM, I

G. linneiana morph. Y by I*

G. mariei Banner & Blow, 1960 by AM, I

G. obliqua Herm, 1965 by I

G. orientalis El Naggat, 1966 by C, AM, I

G. orientalis-*G. esnehensis* intermediate form by I

G. orientalis-*G. falsostuarti* ?intermediate form by I

G. pozaryskae Peryt, 1980 by I

G. rosetta (Carsey, 1926) by C, AM, I

G. rosetta-*Gtl. insignis* intermediate form by I

G. rugosa (Marie, 1941) by I

G. tricarinata (Quereau, 1893) by I
G. tricarinata morph. Y by I*
G. ventricosa White, 1928 by C, AM, I
G. ventricosa morph. Z by I*
G. ventricosiformis Maslakova, 1978 by I
G. sp. 1 (nov. sp.?) by I*
G. sp. 1-G. falsostuarti intermediate form by I*
G. sp. 3 by I*
Genus *Globotruncanella* Reiss, 1957 emend. Robaszynski et al., 1984
Gl. havanensis (Voorwijk, 1937) by AM, I
Gl. petaloidea (Gandolfi) by AM
Genus *Globotruncanita* Reiss, 1957 emend. Robaszynski et al., 1984, Loeblich & Tappan, 1988
Gt. angulata (Tilev, 1951) by AM, I
Rd. calcarata?/*Gt. angulata*? intermediate form by C
Gt. atlantica (Caron, 1972) by AM, I
Gt. conica (White, 1928) by AM, I
Gt. elevata (Brotzen, 1934) by C, AM, I
Gt. fareedi (El-Naggar) by AM
Gt. insignis?/*Gt. angulata*? intermediate form by C
Gt. insignis (Gandolfi) by C, AM
Gt. pettersi (Gandolfi, 1955) by I
Gt. stuarti (de Lapparent, 1928) by C, AM, I
Gt. stuarti-Gt. conica intermediate form by I
Gt. stuartiformis (Dalbiez, 1955) by C, AM, I
Gt. stuartiformis-Gt. stuarti intermediate form by I*
Gt. stuartoconica Solakius & Salaj, 1985 by I
Genus *Globotruncanitella* (new genus) by I* (= *Globotruncanita* in C & AM)
Gtl. tercensis n. sp. by I*
Gtl. insignis (Gandolfi, 1955) by I
Genus *Gublerina*
Gublerina acuta De Klasz by AM
Genus *Guembelitra*
Guembelitra cretacea Cushman by AM
Genus *Hedbergella*
Hedbergella holmdelensis Olsson by AM
Hedbergella monmouthensis (Olsson) by AM
Genus *Heterohelix*
Heterohelix glabrans (Cushman) by AM
Heterohelix globulosa (Ehrenberg) by AM
Heterohelix labellosa Nederbragt by AM
Heterohelix navarroensis (Loeblich) by AM
Heterohelix planata (Cushman) by AM
Heterohelix pulchra (Brotzen) by AM
Heterohelix punctulata (Cushman) by AM
Genus *Kassabiana* Salaj, 1984 emend. Salaj & Solakius, 1984
K. falsocalcarata Kerdany & Abdelsalam, 1969 by I
Genus *Marginotruncana* Hofker, 1956 emend. Porthault, 1970 in Donze et al. 1970

M. coronata (Bolli, 1945) by I
M. marginata (Reuss, 1985) by C, AM, I
M. pseudolinneiana Pessagno, 1967 by C?, I
M. sigali by C?
M. sinuosa Porthault in Donze et al., 1970 by C?, AM, I
M. spinea (Kikoine, 1947) by I
M. undulata (Lehman) by AM
Genus *Morozovella* Mc. Govran, 1968
Mo. sp. cf. Mo. marginodentata (Subbotina, 1953) by I
Genus *Planoglobulina*
Planoglobulina carseyae (Plummer) by AM
Planoglobulina riograndensis (Martin) by AM
Genus *Plummerita* Brönnimann, 1952
Pl. hantkeninoides (Brönnimann, 1952) by I
Genus *Pseudoguembelina* Brönnimann & Brown, 1953, emend. Pessagno, 1967
Pseudoguembelina costulata (Cushman) by AM
Pseudoguembelina excolata (Cushman) by AM
Pseudoguembelina palpebra Brönnimann & Brown by AM
Pseudoguembelina sp. by I
Genus *Pseudotextularia* Rzehak, 1891
Ps. elegans (Rzehak, 1891) by AM, I
Ps. nuttalli (Voorwijk) by AM
Genus *Racemiguembelina* Montanaro Galitelli, 1951, emend. Smith & Pessagno 1973
Racemiguembelina sp. by I
Genus *Radotruncana* El Naggar, 1971 (= *Globotruncanita* by C)
Rd. calcarata (Cushman, 1927) by I
Rd. subspinosa (Pessagno, 1960) by C, AM, I
Rd. subspinosa-Rd. calcarata intermediate form by I
Genus *Rugoglobigerina* Brönnimann, 1952, emend. Pessagno, 1967
R. hexacamerata Brönnimann by AM
R. macrocephala Brönnimann, 1952 by AM, I
R. milamensis Smith & Pessagno, 1973 by I
R. pennyi Brönnimann, 1952 by AM, I
R. rotundata Brönnimann, 1952 by AM, I
R. rugosa (Plummer, 1926) by AM, I
R. rugosa-R. hexacamarata intermediate form by I
R. scotti Brönnimann by AM
R. tradinghousensis Pessagno, 1967 by I
R. spp. by C, I
Genus *Rugotruncana* Brönnimann & Brown, 1956, emend. Pessagno, 1967
Rg. subcircumnodifer (Gandolfi, 1955) by I
Rugotruncana sp. by I
Genus *Sigalitruncana* Korchagin, 1982
S. pileoliformis (Lamolda, 1977) by I
S. sigali (Reichel, 1949) by I

Genus *Ventilabrella* Cushman, 1928, emend. Martin,
1972
V. glabrata (Cushman, 1938) by I

V. multicamerata De Klasz, 1953 by I
Genus *Whiteinella* Pessagno, 1967
W. baltica Douglas & Rankin, by I